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MORPHOMETRIC ANALYSIS OF TENGLI MICRO-WATERSHED USING REMOTE SENSING AND GIS

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ABSTRACT

The study was conducted in Tengli micro-watershed and was delineated on the Arc GIS platform. The study area is falling under the Survey of India toposheet of E43R3 and E43R4 (1:50,000). The drainage pattern of the study area is dendritic with stream order III and lower streams order dominated in the Tengli watershed. The bifurcation ratio (R_b) was 2.75 which show that on undistorted geologic structure (Basalt and lime stone complex). The circulatory ratio (R_c) (1.05), Compactness Co-efficient (C_c) (1.08) and Farm factor R_f (0.86) value indicates watershed was more circular in shape, less elongated with higher peak flows for shorter duration precipitation with high intensity. The drainage density (1.64 km km^{-2}) and stream frequency (1.41 No.km^{-2}) indicates the watershed is having impermeable sub-surface material and sparse vegetation. Estimated value of relief (H) was 32 m, based on which relief ratio (S') and Stream slope (S) were found to be 0.011 and 5.23 m km^{-1} respectively. This is an indication of possibly moderate soil erosion.

***KEYWORDS:** Arc GIS, Remote Sensing, DEM & Morphometric Analysis*

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Original Article

INTRODUCTION

Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler, 1964). Morphometric analysis requires measurement of linear features, aerial aspects and gradient of channel network of the drainage basin. Identification of drainage networks within basins or sub basins can be achieved using traditional methods such as field observations and topographic maps or alternatively with advanced methods using remote sensing and GIS (Sreedevi *et al.*, 2009). In traditional methods, it is difficult to examine all drainage networks from field observations due to their extent throughout rough terrain. Drainage characteristics of many river basins and sub basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1952). Morphometric analysis using GIS technique has emerged as a powerful tool in recent years. GIS technique is very useful in analysing the drainage morphometry. In India, some of the recent studies on morphometric analysis using remote sensing and GIS technique were carried out by Srinivasa *et al.* (2004) and Chopra *et al.* (2005). More recently, Sharma *et al.* (2010) have carried out morphometric analysis of sub-watersheds of 'Uttala' river, which is a tributary of 'Son' river in central India. Evaluation of morphometric parameters necessitates the analysis of various drainage parameters such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, drainage density, stream frequency, bifurcation ratio, basin relief and Ruggedness number. The main objective of this study is using GIS technology to compute various morphometric parameters of

Tengli micro watershed characteristics.

MATERIALS AND METHODS

The study was conducted in Tengli micro watershed (4D5B8Z1c) is part of Mulkod sub watershed, Chitapur taluk, Kalaburagi district. Located in between the longitude of 77°1' and 77°13'1"E and latitude 17°24'3" and 17°26'8" N. It is falling under the Survey of India toposheet of E43R3 and E43R4 (1:50,000). (Figure 3.1) shows the location map of study area. It is located 39 km towards East from District head quarters Kalaburagi. The parameters had been conveniently worked out from the land resource inventarisation followed by interpretation of SoI toposheet, cadastral maps, satellite images, and project reports were used as sources of data. The information was also confirmed by field traverse. Remote sensing and GIS techniques were used to distinguish and quantify the morphological features and characteristics of watershed. The drainage map of the study area was used for quantitative geomorphological analysis of both linear, aerial and relief aspects of the drainage basin (Chow, 1962). Same was shown in figure 3.2.

Linear Aspects of Drainage Network

Stream Order

The term stream order is a measure of the position of a stream in the hierarchy of tributaries (Strahler., 1964). Accordingly, the 1st order streams are those, which have no tributaries. The 2nd order streams are those, which have tributaries of only of 1st order streams. Where two 2nd order streams join, a segment of 3rd order would be formed. When two 3rd order segments joining 4th order stream would be formed and so on. In case of two different orders meets the highest order would become the order of the new segment. The stream order in the Tengli micro watershed were digitized under Arc GIS environment and the same are shown in figure3.2

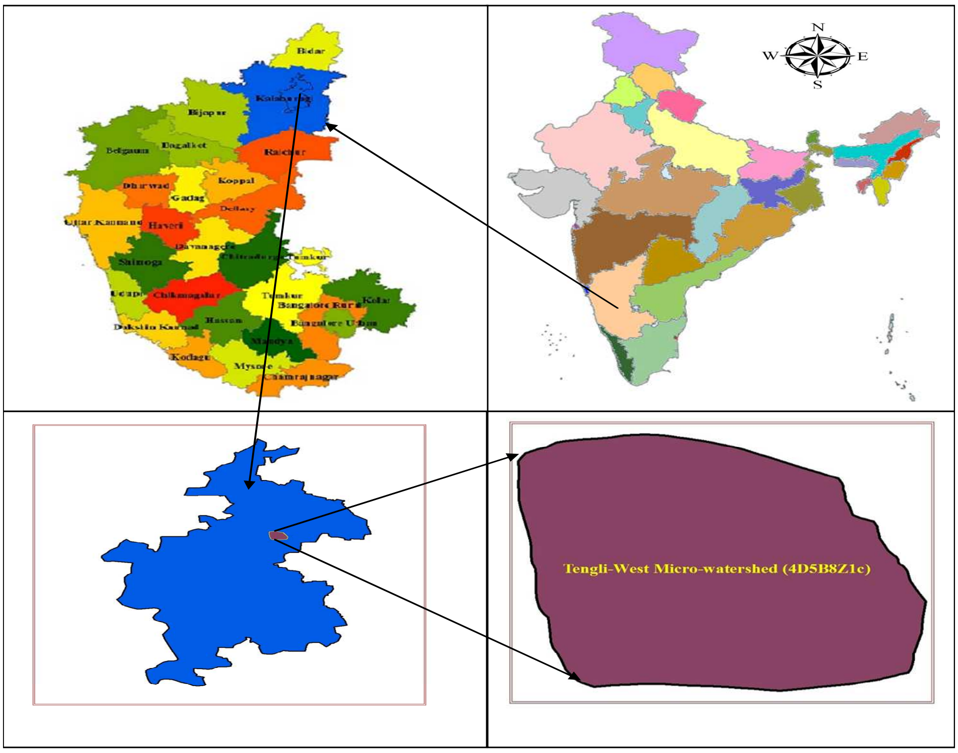

Figure 3.1: Location Map of Study Area of Tengli Micro Watershed (4D5B8Z1c)

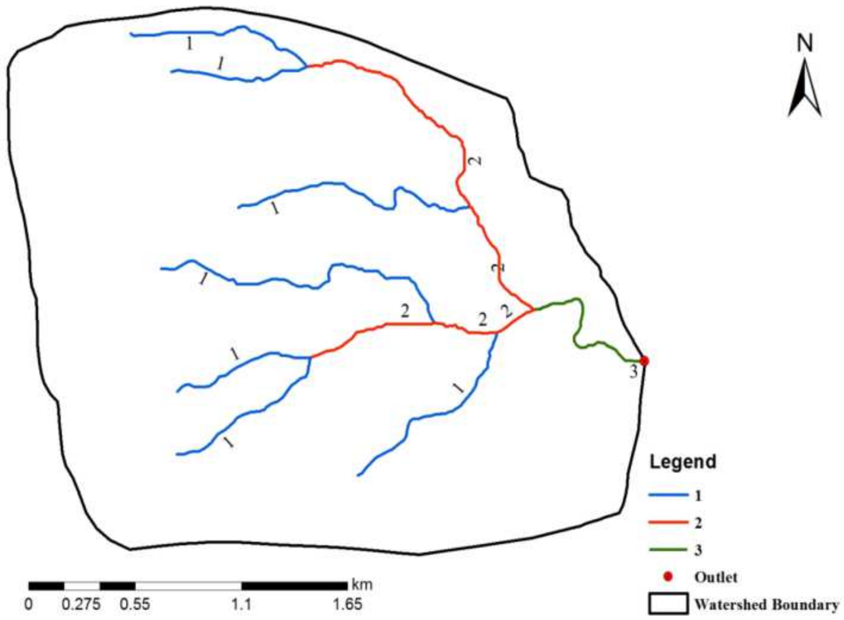

Figure 3.2: Drainage Map of Tengli micro Watershed

Basin Length (L_b)

It is defined as the maximum length of the basin measured from the outlet.

Average Basin Width (B)

It is the ratio of basin area to the basin length of the watershed and is expressed as

$$B = \left(\frac{A}{L_b}\right)$$

where,

A = basin area, km^2

L_b = basin length, km

Basin area is estimated from the SOI toposheet delineated under Arc GIS platform.

Bifurcation Ratio (R_b)

The term bifurcation ratio (R_b) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order.

$$R_b = \left(\frac{N_u}{N_{u+1}}\right)$$

where,

N_u = number of stream segments of order ‘u’.

N_{u+1} = number of stream segments of next higher order ‘u+1’.

Stream Length

Length of the stream is indicative of the contributing areas of the basin of that order. Generally, cumulative length of streams of a particular order is measured, and the mean length (Lu) of that order stream (u) is obtained by dividing cumulative stream length by the number of segments of that order (Nu). It is expressed as

$$\overline{L} = \frac{\sum_{i=1}^{N} L_u}{N_u}$$

where,

L_u = mean length of channel of order u.

N_u = number of stream segment of order u.

Main Valley Length (L_v)

It was measured as the longest length across the valley from extreme of drainage divide to gauging station.

Main Stream Length (L_c)

The total length of the longest segment of each order along the valley of watershed was measured in km up to gauging station.

Length to Centre of Area (L_{CA})

It was measured as the length along the main stream from the point on the stream nearest to centre of gravity of area up to gauging station.

Stream Area

sArea of the stream is indicative of the contributing areas of the basin of that order. Generally, cumulative area of streams of a particular order is measured, and the mean area (Au) of that order stream (u) is obtained by dividing cumulative stream area by the number of segments of that order (Nu). It is expressed as

$$\overline{A} = \frac{\sum_{i=1}^{N} A_u}{N_u}$$

where,

A_u = mean area of order u.

N_u = number of stream segment of order u.

Areal Aspects of Drainage Network

The shape of basin affects stream flow hydrographs and peak flow. The identified parameters including Form factor (R_f), Circularity ratio (R_c), Compactness co-efficient, Elongation ratio (R_e) and Texture ratio (R_t) were selected to

describe the watershed shape (Chow.,1962).

Form Factor (R_f)

sIt is defined as the ratio of area of the basin to the square of the length of basin (Horton, 1932).

$$R_f = \frac{A}{L_b^2}$$

where,

A = area of the basin, km^2

L_b = length of the basin, km

Circulatory Ratio (R_c)

It is the ratio of circumference of a circle whose area is equal to the area of that of basin to the basin perimeter. Mathematically it is expressed and calculated as follows

$$R_C = \left(\frac{P_C}{P}\right) = \left(\frac{2\sqrt{\pi A}}{P}\right)$$

where,

R_c = circulatory ratio.

A = area of the basin, km^2

P = basin perimeter, km

P_c = perimeter of the circle having equal area as that of the drainage basin

Compactness Coefficient (C_C)

It is defined as the ratio of the perimeter of the basin to the circumference of a circle whose area is equal to the area of the basin. It is the inverse of circularity ratio and mathematically expressed as

$$C_C = \frac{P}{2\sqrt{\pi A}}$$

where,

C_C = compactness coefficient

A = area of the basin, km^2

P = basin perimeter, km

Elongation Ratio (R_e)

It is defined as the ratio of diameter of a circle which has same area as the basin to the basin length Schumm (1954) expressed as

$$R_e = \left(\frac{D_C}{L_b}\right) = \left(\frac{2}{L_b}\right)\sqrt{\frac{A}{\pi}}$$

where,

R_e = elongation ratio

Dc = diameter of the circle having same area as that of the basin, km

L_b = basin length, km

A = basin area, km^2

Texture Ratio (R_t)

It is defined as the number of first order streams per unit perimeter of the drainage basin Horton (1932).

$$R_t = \left(\frac{N_1}{P}\right)$$

where,

R_t = texture ratio, No. km^{-1}

N_1 = number of first order streams.

P = basin perimeter, km

Drainage Density (D_d)

It is treated as an important indicator of linear scale of land form elements in the stream eroded topography. Horton (1932) defined drainage density (D_d) as the ratio of total length of all stream segments within a specified basin to the basin area.

$$D_d = \left(\frac{L}{A}\right)$$

where,

D_d = drainage density, km^{-1}

L = length of all stream segments, km

A = area of the basin, km^2

Stream Frequency (F_u)

Stream frequency is defined as the number of stream segments per unit basin area Horton (1932) and is given as

$$F_u = \left(\frac{N}{A}\right)$$

where,

F_u = stream frequency, No km^{-2}

N = total number of stream segments of all orders,

A = basin area, km^2

Relief Aspects of Stream Network

Relief aspects of stream network plays an important role in identifying the overall steepness of the drainage basin and is also considered as an indicator for the intensity of erosion processes operating at basins slope.

Watershed Relief (H)

Watershed relief (H) is the elevation difference between basin mouth (discharge point) and the highest point on the basin perimeter. The maximum watershed relief is obtained from the available contour maps of the watershed (Figure 3.3) and expressed in meter. In the present study contour map was prepared by DEM on Arc GIS platform. The results are listed in Table 3.2c.

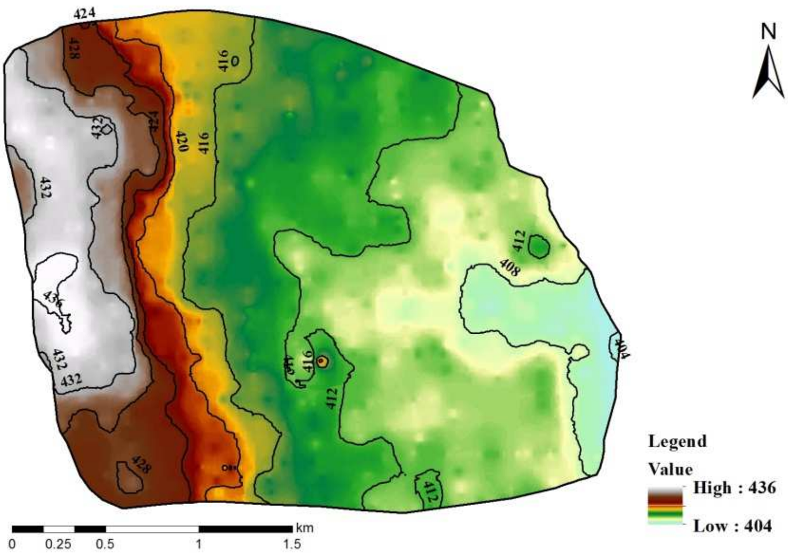

Figure 3.3: Contour Map of Tengli Micro Watershed

Stream Slope (S)

The stream slope has profound effect on the velocity of flow and in turn on the discharge from the drainage area. The slope of the stream is computed as the fall from the head of the first order channel to the gauging station divided by the main stream length (L_c). The obtained results are listed in Table 3.2c.

Relief Ratio (S')

Schumm (1954) defined the relief ratio (R_r) as the ratio of maximum watershed relief divided by the maximum watershed length. It is computed using following expression.

$$S' = \left(\frac{H}{Lb}\right)$$

where,

S' = relief ratio

H = watershed relief, km

L_b = basin length, km

RESULTS AND DISCUSSIONS

Table 3.2a: Linear Aspects of Drainage Network

Sl. No	Horton's Characteristics	Observed Values
1	Length of Basin	2870.00 m
2	Average Basin Width	2471.20 m
3	Number of stream order	
	I	7
	II	2
	III	1
4	Bifurcation Ratio (R_b)	
	BR1	3.5
	BR2	2
	Average	2.75
5	Stream length (L_u)	
	I	7520.00 m
	II	3200.00 m
	III	890.00 m
6	Mean stream length (Lū)	
	I	1070 m
	II	1600 m
	III	890 m
7	Stream length ratio (L_u)	
	RL1	1.50
	RL2	0.56
	Average	1.03
8	Main Valley length (L_v)	3.82 km
	Main stream length (L_c)	3.60 km
	Length to centre of area (L_{CA})	2.83 km
9	Stream area (A_u)	
	I	5.25 km^2
	II	1.22 km^2
	III	0.62 km^2
10	Mean stream area (Aū)	
	I	0.75 km^2
	II	0.61 km^2
	III	0.62 km^2
11	Stream area ratio (R_A)	
	RA1	0.81
	RA2	1.02
	Average	0.92

Table 3.2b: Areal Aspects of Drainage Network

Sl. No	Shape Factor	Observed Values	Permissible Values
1	Area	709.25 ha	
2	Perimeter	10165 m	
3	Drainage density (D_d)	1.64 km km^{-2}	
4	Stream frequency (F_u)	1.41 No. km^{-2}	
5	Texture ratio (R_t)	0.7	
6	Farm factor (R_f)	0.86	< 1

Table 3.2b: Contd.,			
7	Circulatory ratio (R_c)	0.93	≤ 1
8	Compactness co-efficient (C_c)	1.08	≥ 1
9	Elongation ratio (R_e)	1.05	≤ 1

Table 3.2c: Relief Aspects of Stream Network

Sl. No	Relief aspects of Stream Network	Observed Values
1	Relief (H)	0.32 km
2	Stream slope (S)	5.23 m km^{-1}
3	Relief ratio (S')	0.011

It is learnt that the Horton's relations which explore behaviour of both underlying rock system and overlaying morphological character including linear and areal interrelationship among different stream orders and also with basin slope characteristics (gravity effect). The summation of 1st order streams is having larger contributing area (5.25 km^2) followed by 2nd order stream (1.22 km^2) and then 3rd order (0.62 km^2) and as they channelized towards outlet, they get joined with reduced number in logarithmic sequences. The total stream lengths in 1st, 2nd and 3rd orders were measured to 7520 m, 3200 m and 890 m, respectively. Imran *et al.* (2011) reported that higher the stream order, longer the length of streams are noticed in nature. Horton's laws of stream lengths support the theory that geometrical similarity is preserved generally in watershed with increase in order.

In the selected study area bifurcation ratio (R_b) varies from 3.5 to 2.0 and the mean bifurcation of the entire micro watershed is 2.75 which shows that on undistorted geologic structure (Basalt and lime stone complex) and existence of drainage system on of moderate peaks and lower order streams are approximately 2.75 times more than subsequent higher order.

The areal aspects effectively defined the degree of relative elongation or compactness. In other words they have helped to configure the extent of irregularity of drainage area from circular shape. The basins with higher form factor (R_f) are normally circular and have high peak flows for shorter duration, whereas elongated basins with lower values of form factor have low peak flows for longer duration (Das and Mukherjee, 2005). In the present study, R_f (0.86) more or less circular in nature with higher peak flows for shorter duration (tp of 1.40). Flood flows of such circular basin are difficult to manage than from the elongated basins (Mahadevaswamy *et al*. 2011).

The circulatory ratio (R_c) is influenced by the length and frequency of streams, geological structures, land use/cover, climate, relief and slope of the basin (Chopra *et al.* 2005). In the present study high R_c (0.93) value indicate that they are more or less circular in shape and are characterized by high to moderate relief and drainage system is structurally controlled. According to Strahler (1964), the values of elongation ratio (R_e) can be grouped into three categories, *viz.* (a) circular basin (>0.9), (b) oval basin (0.9 to 0.8) and (c) elongated basin (<0.7). Lower value of Re infers more elongated basin whereas larger value indicates more circular in shape of the basin. In the present study high R_e (1.05) value indicates more circular in shape of the basin.

The Compactness Co-efficient (C_c) is indirectly related with the elongation of the basin area. Lower values indicate more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion (Patel *et al.* 2012). In the present study high C_c (1.08) indicates watershed was less elongated and subjected to high erosion. The drainage density and stream frequency for the watershed was 1.64 km km^{-2} and 1.41 No.km^{-2} indicates the watershed was having impermeable sub-surface material and sparse vegetation these results are in agreement with the earlier findings

by Horton (1945). Estimated value of relief (H) was 32 m, based on which relief ratio (S') and Stream slope (S) were found to be 0.011 and 5.23 m km^{-1} respectively. This is an indication of possibly moderate soil erosion.

CONCLUSIONS

Geologically of watershed was underline by Basalt and Lime stone complex prevailed with undistorted geological structure. Whereas, morphologically, Tengli micro watershed having 3rd order dendritic stream network has near to circular in shape (form factor of 0.86) which produces relatively higher peak of shorter duration (t_p of 1.41 h). Stream network analysis based on Horton's hypothesis (R_b of 2.75, L_u of 1.03 and L_c of 3.60 km) and interrelations of linear, areal and relief aspects of watershed were evaluated. The moderate relief ratio of 0.011 shows accumulation of runoff to in the stream network with longer lengths of lower order streams and shorter lengths of higher order streams.

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